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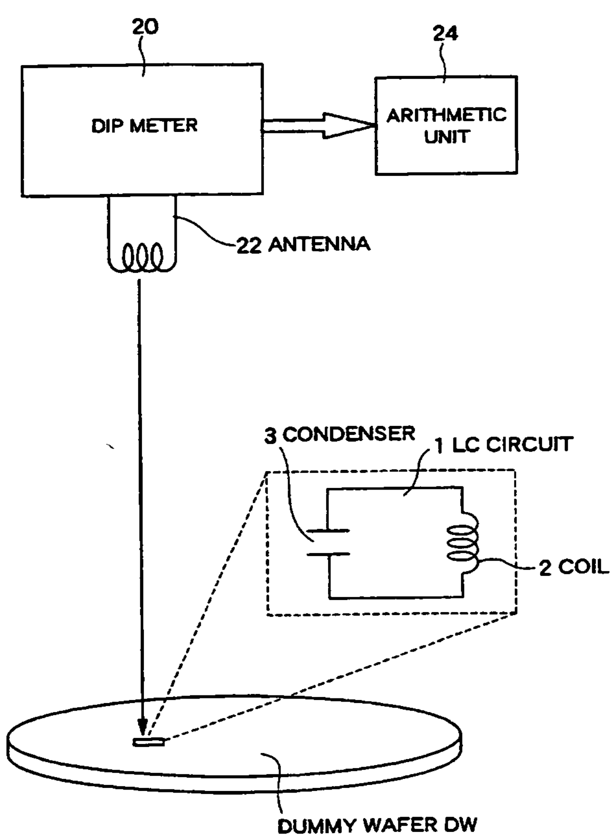
(54) Title: METHOD AND APPARATUS FOR MEASURING THE TEMPERATURE OF A SEMICONDUCTOR SUBSTRATE BY MEANS OF A RESONANT CIRCUIT



(57) Abstract: A substrate temperature measuring method, a substrate processing method, substrate temperature measuring equipment and semiconductor manufacturing equipment that can measure more accurately a temperature of and can process more precisely a substrate than in existing ones are provided. Electric energy is converted into electromagnetic wave energy, an electromagnetic wave involving the converted electromagnetic wave energy being irradiated on a resonant circuit disposed on a substrate. A voltage or a current involving electric energy is detected to detect a resonance frequency of a resonant circuit. From the detected resonance frequency, a temperature of a substrate is obtained. Thereby, by making use of at least one resonant circuit disposed on a substrate, a temperature of the substrate can be measured with high precision.

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METHOD AND APPARATUS FOR MESURING THE TEMPERATURE OF A SEMICONDUCTOR SUBSTRATE BY MEANS OF A RESONANT CIRCUIT

Technical Field

The present invention relates to a substrate temperature measuring method, substrate processing, substrate temperature measuring equipment, and semiconductor manufacturing equipment. In particular, the present invention relates to a substrate temperature measuring method, substrate processing, substrate temperature measuring equipment, and semiconductor manufacturing equipment preferably applicable to a semiconductor wafer (hereafter, wafer) in a manufacturing process of a semiconductor device and a LCD substrate in a manufacturing process of a liquid crystal display (LCD).

Background Art

Recently, in a manufacturing process of a semiconductor device or a liquid crystal display (LCD), a circuit pattern thereof is in a tendency of getting finely formed. Accordingly, to improve accuracy of processing in various kinds of processes, the respective processes are required to implement under accurate control of a temperature of the wafer or LCD substrate.

So far, as a method of measuring a temperature of a wafer in a manufacturing process of a semiconductor device and of a LCD substrate in a manufacturing process of a liquid crystal display, a temperature measuring method utilizing a thermocouple and a radiation thermometer are well known.

However, of the aforementioned temperature measuring methods, the one employing a thermocouple requires a secured contact of the thermocouple with a substrate or the like that is a measuring object, and furthermore a lead wire connected to the thermocouple being necessitated to be routed.

On the other hand, in the measuring method employing the radiation thermometer, noncontact temperature measurement can be advantageously carried out on the basis of radiant energy from a wafer. However, emissivity varies depending on the temperature, and stray light adversely affects. As a result, an accurate temperature measurement has been difficult.

With an intent to overcome the aforementioned problems, Japanese Patent Application Publication No. HEI 10-142068 discloses a temperature measuring method utilizing miniature temperature measuring equipment. Here, the miniature temperature measuring equipment comprises a temperature measuring portion, a controller, a memory, a processor, an antenna for transmitting/receiving data and an antenna for transmitting/receiving power, and is stuck on a wafer. Power is supplied to the temperature measuring equipment from the outside thereof by means of microwaves to operate the controller and processor, thereby letting send out

temperature measuring signals.

Disclosure of the Invention

However, in the aforementioned existing method, electronic components such as the controller, the processor, the memory and the like are assembled on a wafer to be temperature measured. Accordingly, characteristics of these electronic components themselves vary due to the temperature to affect on the temperature in measuring signals that is sent out, resulting in an inaccurate temperature measurement.

The present invention is carried out to overcome the aforementioned existing problems. The object of the present invention is to provide a substrate temperature measuring method, substrate processing, substrate temperature measuring equipment and semiconductor manufacturing equipment that are capable of measuring a substrate temperature more accurately than the existing method can and of processing the substrate with accuracy.

A substrate temperature measuring method involving an invention of claim 1 is one utilizing at least one resonant circuit disposed on a substrate. The method comprises the steps of converting electric energy into electromagnetic wave energy to irradiate on the resonant circuit, detecting a voltage or a current involving the electric energy, and obtaining a temperature of the substrate from a detected resonance frequency. In the step of converting electric energy into electromagnetic wave energy to irradiate on the resonant circuit, electric energy is converted into

electromagnetic wave energy, followed by irradiating electromagnetic waves involving the converted electromagnetic wave energy on the resonant circuit. In the step of detecting the voltage or the current, the voltage or the current involving the electric energy is detected to detect the resonance frequency of the resonant circuit.

A substrate processing involving an invention of claim 7 comprises the processes of measuring a temperature of a product substrate by means of a substrate temperature measuring method and of changing, on the basis of the temperature measurement, processing conditions to process the product substrate. Here, the substrate temperature measuring method makes use of at least one resonant circuit disposed on the product substrate. In the process of measuring the temperature of the product substrate, the temperature measuring method comprises the steps of converting electric energy into electromagnetic wave energy, detecting a voltage or a current involving the electric energy, and obtaining a temperature of the substrate from a detected resonance frequency. In the step of converting electric energy into electromagnetic wave energy, the electric energy is converted into the electromagnetic wave energy, followed by irradiating electromagnetic waves involving the converted electromagnetic wave energy on the resonant circuit. In the step of detecting the voltage or the current, the voltage or the current involving the electric energy is detected to detect the resonance frequency of the resonant circuit.

A substrate temperature measuring method involving an

invention of claim 9 is one measuring a temperature of a substrate thereon a plurality of resonant circuits are disposed. The method comprises the steps of converting electric energy into electromagnetic wave energy, moving a electromagnetic wave irradiation portion, detecting a voltage or a current, and obtaining from respectively detected resonant frequencies temperatures of a plurality of portions on the substrate. In the step of converting electric energy into electromagnetic wave energy, the electric energy is converted into the electromagnetic wave energy to irradiate electromagnetic waves involving the converted electromagnetic wave energy from the electromagnetic wave irradiation portion toward the substrate. In the step of detecting the voltage or the current, the voltage or the current involving the electric energy is detected, during the movement, to detect resonance frequencies each of the plurality of the resonant circuits.

Temperature measuring equipment involving an invention of claim 12 comprises an electromagnetic waves irradiation portion, a resonance frequency detecting portion, and a temperature determining portion. Here, in an electromagnetic waves irradiation portion, electric energy is converted into electromagnetic wave energy, electromagnetic waves involving the converted electromagnetic wave energy being irradiated on a resonant circuit on a substrate. In a resonance frequency detecting portion, a voltage or a current involving the electric energy is detected to detect a resonance frequency of the resonant circuit. In a temperature determining

portion, from the detected resonance frequency the temperature of the substrate is obtained.

Semiconductor manufacturing equipment involving an invention of claim 13 comprises a substrate temperature measuring portion and a processing chamber for processing the substrate. The substrate temperature measuring portion has an electromagnetic waves irradiation portion, a resonance frequency detecting portion, and a temperature determining portion. In the electromagnetic wave irradiation portion, electric energy is converted into electromagnetic waves, electromagnetic waves involving the converted electromagnetic energy being irradiated on a resonant circuit on the substrate. In the resonance frequency detecting portion, a voltage or a current involving the electric energy is detected to detect a resonance frequency of the resonant circuit, and a temperature determining portion determines a temperature of the substrate from the detected resonance frequency.

According to the substrate temperature measuring method, the substrate processing, the substrate temperature measuring equipment and the semiconductor manufacturing equipment of the present invention, at least one resonant circuit disposed on the substrate is utilized. By the use of temperature dependence of a resonance frequency of the resonant circuit, without disposing a complicated electronic circuit or the like on the substrate, and without coming into contact with the substrate, a remote temperature measurement of the substrate can be implemented. Furthermore, the substrate can

be processed with accuracy.

Brief Description of the Drawings

Fig. 1 is a conceptual drawing showing a temperature measuring method involving the present invention.

Figs. 2A, 2B, 2C, 2D, 2E and 2F are diagrams showing step by step the steps of forming a resonant circuit utilized in the present invention.

Figs. 3A, 3B, 3C, and 3D, continuation of Figs. 2A through 2F are diagrams showing step by step the steps of forming a resonant circuit utilized in the present invention.

Fig.4 is a diagram showing a relationship between frequency f and energy E of electromagnetic waves irradiated on a resonant circuit.

Fig. 5 is a diagram showing a relationship between resonance frequency fr and temperature T.

Fig. 6 is a diagram showing one example of a relationship between the resonance frequency and temperature in Fig. 5.

Figs. 7A, 7B, 7C, 7D, 7E and 7F are diagrams showing step by step the steps of forming a resonant circuit utilized in the present invention, the steps being different from those shown in Figs. 3A through 3F and Figs. 4A through 4D.

Figs. 8A and 8B, continuation of Figs. 7A through 7F, are diagrams showing step by step the steps of forming a resonant circuit involving the present invention.

Fig. 9 is a front section view showing schematically an aging unit of coated film that is semiconductor manufacturing

equipment involving the present invention.

Fig. 10 is a plan view showing schematically a substrate transfer arm among what are shown in Fig. 9.

Fig. 11 is a plan view showing schematically a cluster tool that is semiconductor manufacturing equipment involving the present invention.

Fig. 12 is a plan view showing the case of measuring a temperature in the cluster tool shown in Fig. 11.

Fig. 13 is a front section view showing schematically an aging unit of coated film that is semiconductor manufacturing equipment involving the present invention, the aging unit being different from one shown in Fig. 9.

Best Modes for Implementing the Invention

As the preferable mode for implementing the present invention, in the substrate temperature measuring method set forth in claim 1, the resonant circuit is directly formed on the substrate.

Furthermore, as the preferable mode for implementing the present invention, in the substrate temperature measuring method set forth in claim 1, the resonant circuit is stuck on the substrate.

Still furthermore, as the preferable mode for implementing the present invention, in the substrate temperature measuring method set forth in claim 1, the resonant circuit is 0.1 MHz to 1000 MHz in its resonance frequency.

Furthermore, as the preferable mode for implementing

the present invention, in the substrate temperature measuring method set forth in claim 1, the substrate is one for temperature measurement.

Still furthermore, as the preferable mode for implementing the present invention, in the substrate temperature measuring method set forth in claim 1, the substrate is a product substrate.

Furthermore, as the preferable mode for implementing the present invention, in the substrate temperature measuring method set forth in claim 1, the substrate is furnished thereon with a plurality of resonant circuits. Electromagnetic waves involving the converted electromagnetic wave energy are irradiated from a plurality of electromagnetic wave irradiation portions onto the plurality of resonant circuits, respectively. The respective resonance frequencies are detected regarding the plurality of resonant circuits each, the step of obtaining the substrate temperature from the detected resonance frequency being carried out of the plurality of portions of the substrate.

Furthermore, as the preferable mode for implementing the present invention, in the substrate temperature measuring method set forth in claim 9, the substrate exists in a substrate processing space. The substrate is transferred into and from the substrate processing space by means of a substrate transfer arm. The substrate transfer arm is furnished with the electromagnetic wave irradiation portion, and the step of moving the electromagnetic wave irradiation portion is carried out, without transferring the substrate,

by moving the substrate transfer arm.

Furthermore, as the preferable mode for implementing the present invention, in the substrate temperature measuring method set forth in claim 10, the step of moving the electromagnetic wave irradiation portion is implemented after the processing of the substrate in the substrate processing space is over.

Still furthermore, as the preferable mode for implementing the present invention, the semiconductor manufacturing equipment set forth in claim 13 further comprises a substrate transfer arm for transferring the substrate into and from the processing chamber. The substrate transfer arm is furnished with the electromagnetic wave irradiation portion of the substrate temperature determining portion.

In the following, embodiments of the present invention will be explained with reference to the drawings.

Fig. 1 shows schematically a temperature measuring method involving an embodiment of the present invention. As shown in the drawing, on a dummy wafer DW as a substrate, a LC circuit 1 is formed as a resonant circuit that resonates at a particular frequency (varies according to temperature).

The LC circuit 1 essentially constituted of a coil 2 and a condenser 3 is directly formed on the dummy wafer DW by means of photolithography or the like that is similar with one used in manufacturing an ordinary semiconductor device.

Furthermore, the aforementioned dummy wafer DW in the present embodiment is configured in a shape similar with that

of a product wafer used for actually manufacturing semiconductor devices, being used only for temperature measurement. That is, similarly with the product wafer, the dummy wafer DW is disposed at a wafer mounting position in a processing chamber such as for instance an oven for heat treatment, etching equipment, and CVD equipment. The equipment is operated similarly with during the actual processing, thereby actual temperature during the processing being measured.

With reference to Figs. 2A through 2F and 3A through 3D, one example of steps of directly forming a LC circuit 1 on a dummy wafer DW due to photolithography or the like will be explained.

First, on a Si layer 10 of the dummy wafer DW, by means for instance of spin coat method, photo resist 11 is uniformly coated, followed by exposing through a mask of a prescribed pattern, by developing, and by copying the corresponding pattern (Figs. 2A and 2B).

Next, with the photo resist 11 as a mask, impurity ions are implanted on the Si layer 10 to form a conductive region 13 of a prescribed shape, followed by ashing to remove the photo resist used as the mask (Figs. 2C and 2D).

Then, on the dummy wafer DW, a dielectric layer that is dielectrics in a condenser, for instance a SiO_2 layer 14, is deposited by means of CVD method or the like. On the SiO_2 layer 14, by means of photolithography or the like with the photo resist as a mask, a contact hole 15 is formed (Figs. 2E and 2F).

Following the above, on the SiO_2 layer 14 and in the contact hole 15, a conductive layer 16 that becomes an electrode layer, for instance a Poly-Si layer or an Al layer is deposited in terms of CVD method or sputtering method. Further thereon, photo resist 17 is coated, followed by exposing and developing. Thereby, a photo resist pattern consisting of an approximately spiral coil portion, a planar condenser portion and an interconnection portion connecting these is formed (Figs. 3A and 3B).

Thereafter, with the aforementioned photo resist pattern as a mask, the conductive layer 16 is etched, after that, due to the ashing the photo resist used as the mask is removed. Thereby, a conductive layer pattern 19 consisting of an approximately spiral coil portion, a planar condenser portion and an interconnection portion connecting these, is formed (Figs. 3C and 3D).

Furthermore, as demands arise, on the LC circuit thus formed, a protective film is stuck.

Thus, on the dummy wafer DW, the conductive region 13 and the conductive layer pattern 19 are connected through the contact hole 15. In addition, with the SiO_2 layer 14 as the dielectric layer interposed, the conductive region 13 and the conductive layer pattern 19 are disposed, and furthermore the LC circuit 1 having the spiral coil portion being directly formed.

The LC circuit 1 is, as the need arises, formed one or more on prescribed positions on the dummy wafer DW, thereby enabling to detect the temperatures of the respective

positions.

In the proximity of the dummy wafer DW thereon the LC circuit 1 is thus formed, as shown in Fig. 1, as a means for detecting the resonance frequency of the LC circuit 1, a dip meter 20 is disposed for instance.

In the aforementioned dip meter 20, from an antenna 22, electromagnetic waves of a prescribed frequency region are oscillated while sweeping. When the frequency of the electromagnetic waves is the resonance frequency of the LC circuit 1, energy is absorbed by the LC circuit 1 and comes down as shown in Fig. 4. By making use of this property, the dip meter 20 is configured detectable of the resonance frequency of the LC circuit 1.

That is, the antenna 22, functioning as the electromagnetic waves irradiation portion, radiates the electromagnetic waves in the air to electromagnetically couple with a conductor where the electromagnetic waves are in interlinkage. Thereby, an oscillator is configured to take in even an external conductor as part of load thereof. Accordingly, when electric energy oscillated in the oscillator is converted into electromagnetic wave energy by means of the antenna 22, by detecting variation due to the frequency of a current or a voltage outputted from the oscillator, the resonance frequency of the LC circuit 1 that is an external circuit can be detected.

Furthermore, a detection result due to the aforementioned dip meter 20 is inputted in a processor 24, thereby a processor 24 calculating a temperature of the dummy

wafer DW from the resonance frequency of the LC circuit 1.

That is, in general, the resonance frequency (fr) of the LC circuit 1, with inductance of the coil 2 L and capacitance of the condenser 3 C, is expressed by

$fr = 1/[2\pi(LC)^{1/2}]$.

Furthermore, the inductance L of the coil 2 and the capacitance C of the condenser 3 are temperature-dependent to vary in values thereof according to the temperature. Accordingly, the resonance frequency also is temperature-dependent. For instance, it varies as shown in a diagram of Fig. 5 where an ordinate is temperature T and an abscissa is resonance frequency fr.

Accordingly, when the relationship between the temperature T of the LC circuit 1 and the resonance frequency fr is previously established to store in the processor 24 as data, from the value of the resonance frequency fr thereof, an accurate temperature of the dummy wafer DW can be obtained.

The aforementioned resonance frequency fr, though may be an arbitrary frequency, from resolving power or the like in the temperature measurement, is preferable to be a frequency in the range of approximately 0.1 MHz to approximately 1000 MHz. Accordingly, so that the resonance frequency of the LC circuit 1 may be in the aforementioned range, the values of the inductance of the coil 2 and the capacitance of the condenser 3 are preferably selected.

For instance, with the values of the inductance of the coil 2 and the capacitance of the condenser 3 of 1 μH and 1pF respectively and the temperature characteristic of the

condenser 3 of -3300 ppm/°C, the relationship of the temperature T and the resonance frequency fr as shown in Fig. 6 can be obtained. From the relationship, the temperature corresponding to the resonance frequency can be obtained by the use of the processor 24.

The dummy wafers DW thereon the aforementioned LC circuit 1 is formed, for instance before starting the processing of the product wafers, are disposed at the wafer processing portions of various kinds of processing equipment. Thereby, the dummy wafers DW are processed similarly with the product wafers, the temperatures at that time being measured.

The temperature measurements at that time are fed back when processing the product wafers. Thereby, the product wafer can be processed in a state more accurately controlled to a desired processing temperature.

For instance, in a series of lithography steps using photo resist for the product wafer, in a so-called oven or the like, the product wafers are heat-treated one by one after mounting on a hot plate. In that case, for instance before starting the processing of the product wafer, the dummy wafer DW is mounted on the aforementioned hot plate to heat-treat similarly with the product wafer.

The antenna 22 of the dip meter 20 is disposed in advance above the oven or the like. Thereby, an actual temperature of the dummy wafer DW during the processing is measured to detect what extent of an error occurs between the preset temperature of the oven and an actual temperature of the dummy wafer DW. When processing the product wafer, the

preset temperature of the oven is adjusted so that such an error may become smaller, thereby the product wafer being processed in a state accurately maintaining a desired processing temperature.

As to the dip meter 20, such a configuration that the antenna portion 22 thereof only is disposed in the neighborhood of the oven and a body portion thereof is disposed distanced from the oven can be taken. Thereby, without suffering an influence of heat from the oven, the temperature of the dummy wafer DW can be measured.

In the aforementioned temperature measurement, it may be required to measure a temperature distribution in a plurality of points of the wafer for instance such as a central portion, a periphery portion and the like. In that case, a plurality of LC circuits 1 corresponding to such measuring points are mounted on the dummy wafer DW, thereby, the temperature distribution at the plurality of measuring points being measured.

In this case, the antennas 22 corresponding to the respective LC circuits 1 in the number thereof may be disposed above the oven, or one or a plurality of antennas 22 may cope with a plurality of LC circuits 1, the position of the antenna 22 being made movable.

Furthermore, when a plurality of antennas 22 are disposed, these antennas 22 can be sequentially electrically switched to use, thereby enabling to reduce the number of the dip meter bodies fewer than that of the antennas.

As explained in the above, according to the present

embodiment, on the dummy wafer DW the LC circuit 1 is directly formed to detect the resonance frequency thereof by means of the dip meter 20. Thereby, without coming into contact with the dummy wafer DW, the temperature of the dummy wafer DW can be accurately measured.

Furthermore, on the dummy wafer DW, there is no need of disposing, other than the LC circuit 1, for instance an amplifier or a processor to measure a temperature. Accordingly, since there is no need of considering an influence of temperature-dependence of these circuits, in a broader temperature range an accurate temperature measurement can be implemented.

Furthermore, on the dummy wafer DW, by the ordinary manufacturing steps of a semiconductor device such as lithography or the like, the LC circuit 1 is formed. Accordingly, by the use of a manufacturing line of an ordinary semiconductor device, on the dummy wafer DW the LC circuit 1 can be formed.

In the aforementioned example, the case where the LC circuit 1 is directly formed on the dummy wafer DW is illustrated. However, for instance, a LC circuit formed on the other thin substrate can be stuck on the dummy wafer DW to use.

Furthermore, other than on the dummy wafer DW, on the product wafer the LC circuit 1 may be directly formed. Alternatively, a LC circuit formed on the other thin substrate is stuck on the product wafer. Thereafter, during the processing of the actual product wafer, the temperature

of the product wafer can be directly measured.

In that case, the temperature of the product wafer being processed can be measured in real time to control the temperature thereof.

The present method can be applied, in addition to the aforementioned heat treatment due to the oven, in all processing such as various kinds of film formation processing, etching, coating of the photo resist and developing. In all of which, the processing is implemented while controlling the temperature.

In the aforementioned example, the case where the resonance frequency is measured by the use of the dip meter 20 is illustrated. However, with the antenna attached to an impedance meter, similarly the resonance frequency can be measured.

Next, with reference to Figs. 7A, 7B, 7C, 7D, 7E and 7F and 8A and 8B, an example of another process of forming the LC circuit 1 on the dummy wafer DW by means of lithography or the like will be explained.

First, on a Si layer 30 on a dummy wafer DW, a SiO_2 layer 31 is formed (Figs. 7A and 7B).

Thereafter, for instance a Poly-Si layer, an Al layer or the like is formed thereon, followed by patterning due to the photolithography. Alternatively, mask sputtering of Al or the like is implemented. Thereby, on the SiO_2 layer 31, a lower electrode layer 32 of a prescribed shape is formed (Figs. 7C and 7D).

Next, on the lower electrode layer 32 a dielectric

layer that becomes dielectrics in a condenser, a SiO_2 layer 33 for instance, is formed due to CVD method or the like. Thereafter, a contact hole 34 is partially formed on the SiO_2 layer 33 in terms of the photolithography or the like with the photo resist (Figs. 7E and 7F).

Further thereafter, on the SiO_2 layer 33 and in the contact hole 34, for instance a Poly-Si layer, an Al layer or the like is formed, followed by patterning by means of the photolithography or the like. Alternatively, mask sputtering of Al or the like is implemented. Thereby, an upper electrode layer 35 of a prescribed shape is formed (Figs. 8A and 8B).

In addition, as needs arise, on the LC circuit formed as mentioned above, a protective film can be put on. The situation is the same with the aforementioned process.

According to the above process too, a LC circuit having the following configuration can be directly formed on the dummy wafer DW (or product wafer). That is, in the LC circuit, the lower and upper electrode layers 32 and 35 are interconnected through the contact hole 34 and disposed with the SiO_2 layer 33 interposed as the dielectric layer, and furthermore there being formed the spiral coil portion.

In the aforementioned two examples, the coil shape of the LC circuit is an approximately spiral one. However, the coil shape, without restricting to the approximately spiral one, can be formed in any shape that can work as coil.

Next, as one example of semiconductor manufacturing equipment that is another embodiment of the present invention, an aging unit of coated film will be explained with reference

to Figs. 9 and 10. Fig. 9 is a front section view showing schematically an aging unit of coated film, Fig. 10 being a plan view showing schematically a substrate transfer arm among what are shown in Fig. 9.

In the present embodiment, the aforementioned substrate temperature measuring method is applied in the aging unit of the coated film to measure a temperature of the wafer after the processing. Thereby, validation of the processing temperature and fine adjustment of the processing temperature on the basis of the measured temperature are made possible.

As shown in Fig. 9, the aging unit of the coated film comprises a heating plate 92, a cap 91, a gas supply route 95, an exhaust route 96, three pieces of elevating pins 94, and a gate valve 97. Here, the heating plate 92 is constituted of for instance ceramics housing a heater 93. The cap 91 comes closely in contact through sealing member with a periphery of the heating plate 92 to form a processing space S that is a processing chamber above the heating plate 92. In the gas supply route 95, gas inlets are formed on a surface of the heating plate 92 to surround a wafer mounted on the heating plate 92. The exhaust route 96 is provided with a sucking opening in a central portion of the cap 91. The three pieces of elevating pins 94 move up and down the wafer between the heating plate 92 and an upper position thereof. The gate valve 97 sends the wafer W in and out of the processing space S.

In the aging unit of coated film, ammonia is vaporized, fed into the processing chamber through the aforementioned

gas supply route 54 and exhausted from the exhaust route 55. Thereby, while the wafer W is heated, the coated film is aged. Such aging is used as a process of forming an interlayer insulating film on the wafer for instance.

A wafer W of which coated film is to be aged, while a rear surface thereof is supported from downside by a wafer transfer arm 98, is sent in the aging unit of which gate valve 97 is opened. At that time, the elevating pins 94 are in a lowered state, the wafer transfer arm being moved horizontally up to a prescribed position of the processing chamber S. The wafer W on the wafer transfer arm inserted into the prescribed position of the processing chamber S is delivered to the elevating pins 94 due to an ascending movement of the elevating pins 94.

Upon the wafer W being delivered onto the elevating pins 94, the wafer transfer arm moves horizontally away from the processing chamber as if retreating. Thereafter, the elevating pins 94 are lowered, the gate valve is closed, and furthermore the wafer W is heated by the heating plate 92 up to a prescribed temperature, thus a state ready for processing the wafer is prepared. In the state, the aforementioned processing for aging is implemented.

After the processing is over, the gate valve 97 is opened, and the arm 98 in a wafer non-transfer state is inserted in the processing space S. On a rear surface of the arm 98, the electromagnetic wave irradiation portion 99 (corresponding to the antenna 22 in Fig. 1) is stuck, by making use of the resonant circuit formed on the wafer W, the

temperature thereof being measured. Accordingly, whether the wafer is processed at the prescribed temperature or not can be known. Furthermore, from the results, output power of the heater 93 of the heating plate 92 can be finely adjusted thereafter.

The wafer transfer arm 98 inserted in the processing space S for measuring the temperature, after measurement, is retreated from the processing space S. Thereafter, the elevating pins 94 are raised to clear the rear surface side of the wafer W, in a space resulted from the clearing the wafer transfer arm 98 being inserted again. Then, the elevating pins 94 are lowered to deliver the wafer W to the wafer transfer arm 98, the wafer W delivered to the wafer transfer arm 98 being sent out of the processing space S.

In the case of the aging unit of coated film explained in the above, the wafer W can be a dummy wafer for temperature measurement or a product wafer in part of which a resonant circuit is built-in in advance.

The electromagnetic wave irradiation portion 99 is disposed distanced from the dip meter or the like, accordingly from the dip meter to a rear surface of the wafer transfer arm 98 a transmission line 100 is extended. In this example, as shown in Fig. 10, the electromagnetic wave irradiation portions 99 are disposed at two places on the rear surface of the wafer transfer arm 98. However, the number of the electromagnetic wave irradiation portions may be appropriately increased or decreased. The disposition on many positions enables to measure simultaneously the

temperatures of many positions on the wafer. Furthermore, with the wafer transfer arm moving in a horizontal direction, with one electromagnetic wave irradiation portion 99, the electromagnetic waves are irradiated in turn on a plurality of resonant circuits on the wafer to measure the temperatures there.

Next, as one example of semiconductor manufacturing equipment that is still another embodiment of the present invention, a cluster tool will be explained with reference to Figs. 11 and 12. Fig. 11 is a plan view showing schematically a cluster tool of semiconductor manufacturing equipment that is an embodiment of the present invention, Fig. 12 being a plan view showing the case where a temperature is measured in the cluster tool shown in Fig. 11.

In the present embodiment, a wafer transfer arm capable of measuring the temperature such as explained in the aforementioned embodiment is installed in a cluster tool. In the cluster tool, a wafer that is a processing object is subjected to various kinds of processing such as film formation, annealing, and removal of native oxide film.

As shown in Fig. 11, the cluster tool is disposed with processing chambers 112 to 115 for carrying out the aforementioned various kinds of processing and a transfer chamber 111 capable of evacuating. The processing chambers 112 to 115 and the transfer chamber 111 are connected through gate valves 118 to 121.

Load lock chambers 116 and 117 are communicated through gate valves 122 and 123 with the transfer chamber 111, and an

processing object can be sent in and out through the gate valves 122 and 123 between the load lock chambers 116 and 117 and the external.

In the processing chambers 112 to 115, susceptors mounting the processing objects each are disposed, the processing object being subjected to various kinds of processing such as film formation, annealing and removal of native oxide film.

To the transfer chamber 111, a wafer transfer arm 126 configured stretchable and revolvable is disposed, delivering the processing object among the respective processing chambers 112 to 115 and between these and the load lock chambers 116 and 117. Furthermore, on the rear surface of the wafer transfer arm 126 the electromagnetic wave irradiation portion 99 is disposed. Though omitted in the drawing, from the electromagnetic wave irradiation portion 99 a transmission line is extended up to a dip meter to connect.

To each of the load lock chambers 116 and 117, a wafer susceptor and a vacuum pump not shown in the drawing are furnished. The wafer transfer arm 126 transfers the processing object mounted on the wafer susceptor to the processing chambers 112 to 115. Thereby, without exposing to the air, the processing object can be delivered.

In the cluster tool, the load lock chambers 116 and 117, the transfer chamber 111 and the processing chambers 112 to 115 all can be independently evacuated. In an ascending order of the load lock chambers 116 and 117, the transfer chamber 111 and the processing chambers 112 to 115, vacuum

can be increased. When sending the processing object from the external into the processing chambers 112 and 115, first the processing object is sent in the load lock chamber 116 or 117. The wafer that is sent in the load lock chamber 116 or 117 is sent in the transfer chamber 111 by means of the wafer transfer arm 126. The processing object that is sent into the transfer chamber 111 is sent in the processing chambers 112 to 115 by means of the wafer transfer arm 126.

Thereby, even when the processing object is sent in and out of the processing chambers 112 to 115, the inside of the processing chambers 112 to 115 can be prevented from being exposed to the atmosphere. Accordingly, the insides of the processing chambers 112 to 115 can be prevented from being contaminated, and particles in the air can be prevented from intruding into the processing chambers 112 to 115. As a result, high precision processing can be realized.

Furthermore, when transferring the processing object from the processing chamber 112 to the chamber 113, even when the processing object is transferred from the processing chamber 113 to the chamber 114, similarly the processing object can be prevented from being contaminated by the air.

When measuring the wafer temperature, as shown in Fig. 12, the wafer transfer arm 126 is inserted in the processing chamber. At that time, the wafer transfer arm 126 is inserted as if holding high upward of the wafer in the processing chamber. Thereby, from the electromagnetic wave irradiation portions 99 disposed on the rear surface of the wafer transfer arm 126 onto the resonant circuits previously

formed on the wafer, electromagnetic waves are irradiated to enable to measure the temperatures of those portions.

By materializing the temperature measuring method involving the aforementioned present invention in the cluster tool, furthermore in the cluster tool, in the various kinds of processing the substrate temperature thereof can be measured immediately thereafter, thereby the validation being confirmed. In addition, according to the result, the processing temperature can be finely adjusted. Accordingly, also from a viewpoint of temperature management, the high precision processing can be realized.

Next, as one example of semiconductor manufacturing equipment that is still another embodiment of the present invention, an aging unit of coated film will be explained with reference to Fig. 13. Fig. 13 is a front section view schematically showing the aging unit of coated film, already explained elements being assigned the same reference numerals.

In the present embodiment, the electromagnetic wave irradiation portion 99 is disposed opposite to the wafer W in the processing space S. Furthermore, though omitted in the drawing, from the electromagnetic wave irradiation portion 99 the transmission line is extended up to a dip meter to connect.

Due to the disposition of the electromagnetic wave irradiation portion 99 in the processing space S, during the processing the temperature of the wafer W can be measured in real time. As a result, the temperature can be adjusted with higher accuracy than in the aforementioned temperature

measurement after the processing. Accordingly, the wafer can be processed with high accuracy.

As explained in the above, according to the present invention, the substrate temperature measuring method, substrate processing, substrate temperature measuring equipment, and semiconductor manufacturing equipment that can accurately measure the temperature of the substrate and can process the substrate with higher accuracy than in the existing method can be provided.

Industrial Applicability

The substrate temperature measuring method and substrate processing involving the present invention can be applied when a semiconductor substrate or a LCD substrate is manufactured. Accordingly, the aforementioned methods can be applied in semiconductor manufacturing industry and LCD manufacturing industry.

Furthermore, the substrate temperature measuring equipment and the semiconductor manufacturing equipment involving the present invention can be used when manufacturing a semiconductor substrate or a LCD substrate, in addition being manufactured in the manufacturing industry of semiconductor manufacturing equipment. Accordingly, the aforementioned equipment can be applied in semiconductor device manufacturing industry, semiconductor manufacturing industry and LCD manufacturing industry.

CLAIMS

1. A substrate temperature measuring method that makes use of at least one resonant circuit disposed on a substrate, comprising the steps of:

converting electric energy into electromagnetic wave energy, an electromagnetic wave involving the converted electromagnetic wave energy being irradiated on the resonant circuit;

detecting a voltage or a current involving the electric energy to detect a resonance frequency of the resonant circuit; and

obtaining a temperature of the substrate from the detected resonance frequency.

2. The substrate temperature measuring method as set forth in claim 1:

wherein the resonant circuit is directly formed on the substrate.

3. The substrate temperature measuring method as set forth in claim 1:

wherein the resonant circuit is stuck on the substrate.

4. The substrate temperature measuring method as set forth in claim 1:

wherein the resonant circuit has a resonance frequency in a range of 0.1 MHz to 1000 MHz.

5. The substrate temperature measuring method as set forth in claim 1:

wherein the substrate is one for temperature

measurement.

6. The substrate temperature measuring method as set forth in claim 1:

wherein the substrate is a product substrate.

7. A method for processing a substrate, comprising the steps of:

measuring a temperature of a product substrate by means of a substrate temperature measuring method making use of at least one resonant circuit disposed on the product substrate and having the steps of, converting electric energy into electromagnetic wave energy, an electromagnetic wave involving the converted electromagnetic wave energy being irradiated on the resonant circuit, detecting a voltage or a current involving the electric energy to detect a resonance frequency of the resonant circuit, and obtaining a temperature of the product substrate from the detected resonance frequency; and

varying processing conditions of the product substrate to process the product substrate, on the basis of the temperature measurements.

8. The substrate temperature measuring method as set forth in claim 1:

wherein the substrate is provided with a plurality of resonant circuits;

the electromagnetic wave involving the converted electromagnetic wave energy is irradiated from a plurality of electromagnetic wave irradiation portions on each of the plurality of resonant circuits;

the resonance frequency is detected of each of the plurality of resonant circuits; and

the step of obtaining the temperature of the substrate from the detected resonance frequency is carried out of a plurality of areas of the substrate.

9. A substrate temperature measuring method of a substrate disposed with a plurality of resonant circuits, comprising the steps of:

converting electric energy into electromagnetic wave energy, an electromagnetic wave involving the converted electromagnetic wave energy being irradiated from an electromagnetic wave irradiation portion directing onto the substrate;

moving the electromagnetic wave irradiation portion;

detecting a voltage or a current involving the electric energy to detect resonance frequencies each of the plurality of resonant circuits, while the moving; and

obtaining temperatures of a plurality of areas of the substrate from the detected resonance frequencies each.

10. The substrate temperature measuring method as set forth in claim 9:

wherein the substrate exists in a substrate processing space, the substrate being moved in and out of the substrate processing space by means of a substrate transfer arm;

the electromagnetic wave irradiation portion is furnished on the substrate transfer arm; and

the step of moving the electromagnetic wave irradiation portion is carried out, without transferring the substrate,

by moving the substrate transfer arm.

11. The substrate temperature measuring method as set forth in claim 10:

wherein the step of moving the electromagnetic wave irradiation portion is implemented after substrate processing is over in the substrate processing space.

12. Substrate temperature measuring equipment, comprising:

an electromagnetic wave irradiation portion by which electric energy is converted into electromagnetic wave energy, an electromagnetic wave involving the converted electromagnetic wave energy being irradiated on a resonant circuit on a substrate;

a resonance frequency detecting portion by which a voltage or a current involving the electric energy is detected to detect a resonance frequency of the resonant circuit; and

a temperature processor by which a temperature of the substrate is obtained from the detected resonance frequency.

13. Semiconductor manufacturing equipment, comprising:

a substrate temperature measuring portion having an electromagnetic wave irradiation portion by which electric energy is converted into electromagnetic wave energy, an electromagnetic wave involving the converted electromagnetic wave energy being irradiated on a resonant circuit on a substrate, a resonance frequency detecting portion by which a voltage or a current involving the electric energy is detected to detect a resonance frequency of the resonant circuit, and a temperature processor by which a temperature

of the substrate is obtained from the detected resonance frequency; and

a processing chamber for processing the substrate.

14. The semiconductor manufacturing equipment as set forth in claim 13, further comprising:

a substrate transfer arm by which the substrate is sent in and out of the processing chamber;

wherein the electromagnetic wave irradiation portion of the substrate temperature measuring portion is disposed on the substrate transfer arm.

FIG. 1

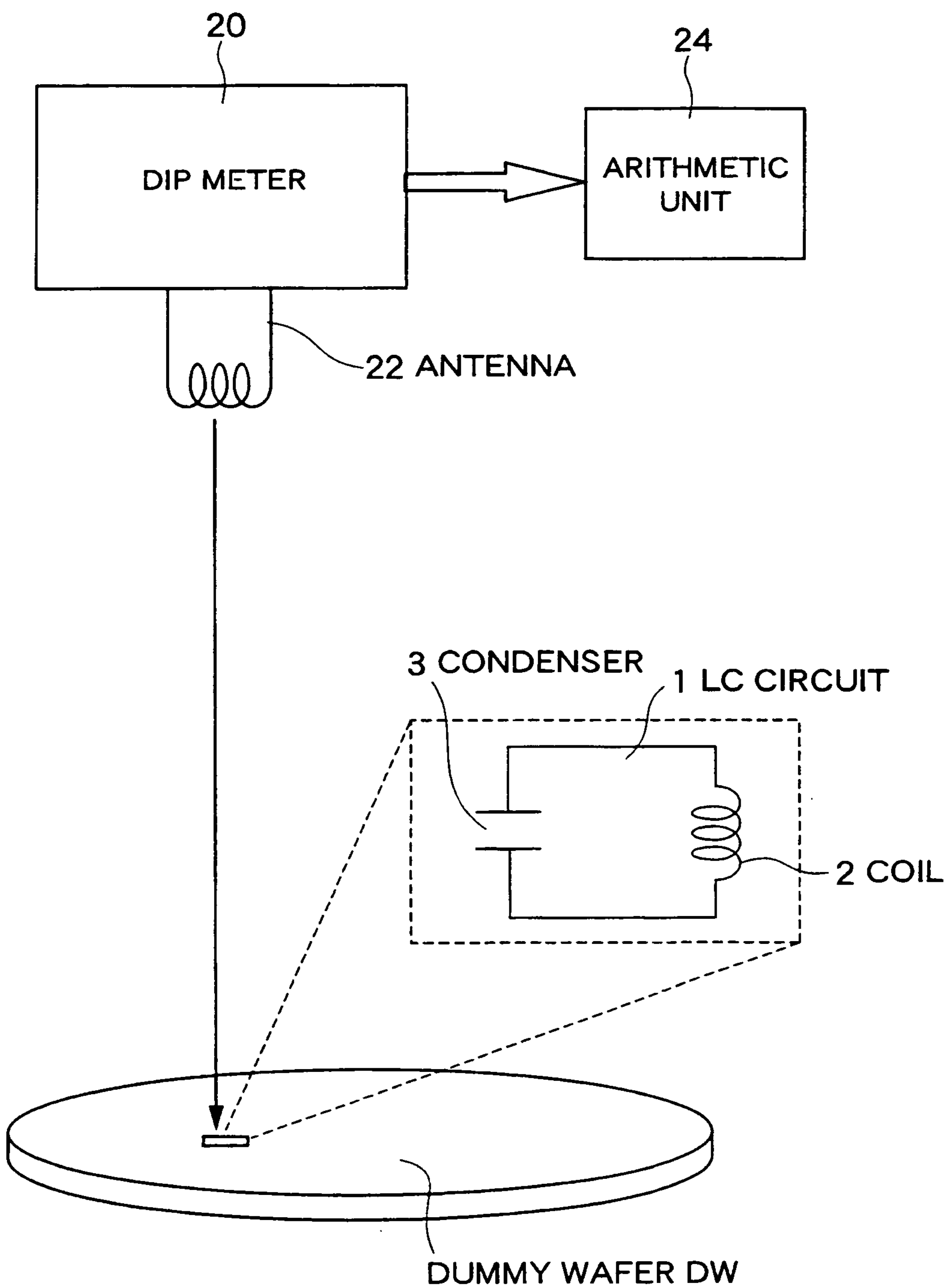

20
24
DIP METER
ARITHMETIC UNIT
22 ANTENNA
3 CONDENSER
1 LC CIRCUIT
2 COIL
DUMMY WAFER DW

FIG. 2A

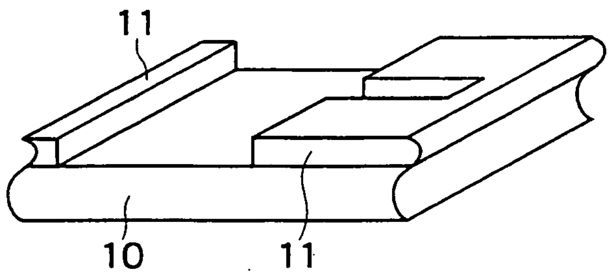


FIG. 2B

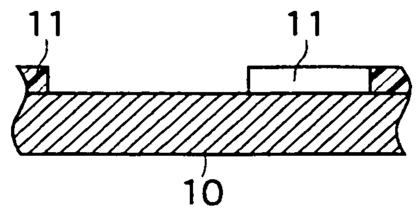


FIG. 2C

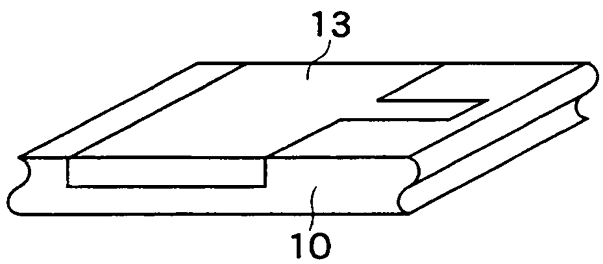


FIG. 2D

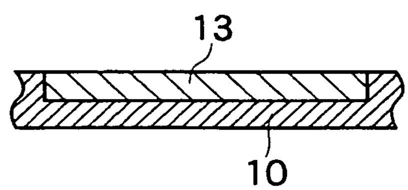


FIG. 2E

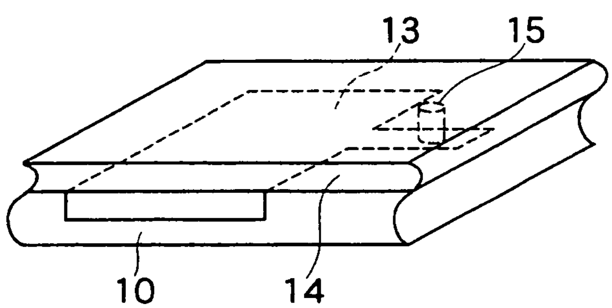


FIG. 2F

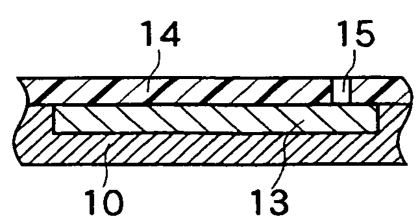


FIG. 3A

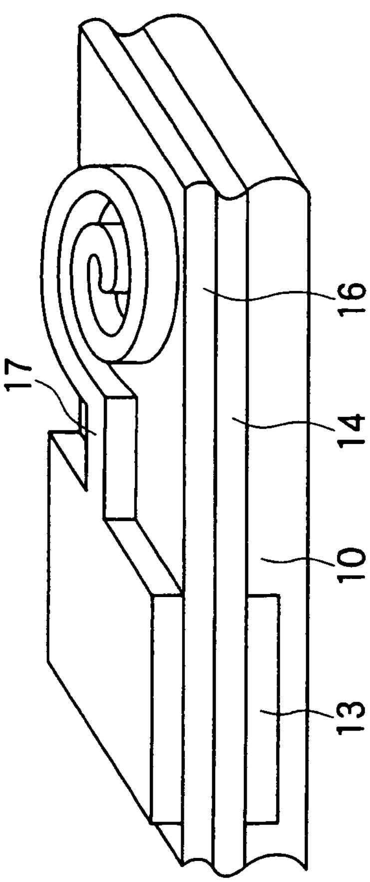


FIG. 3B

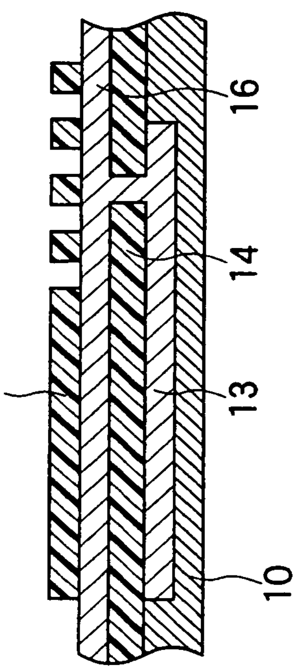


FIG. 3C

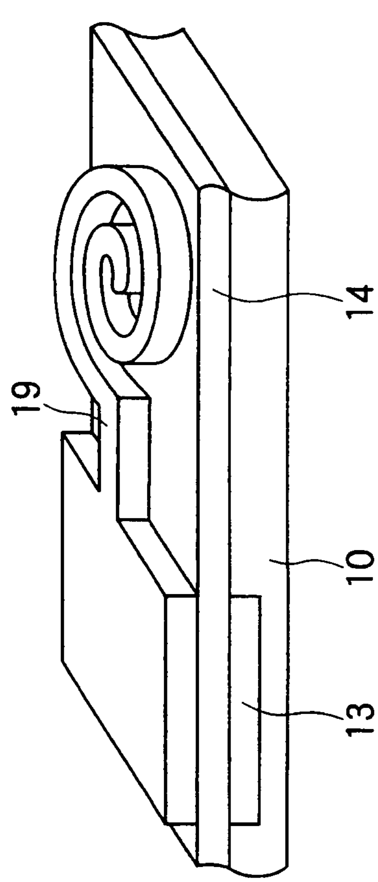


FIG. 3D

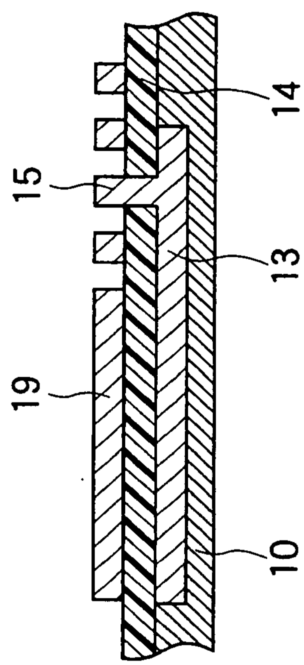


FIG. 4

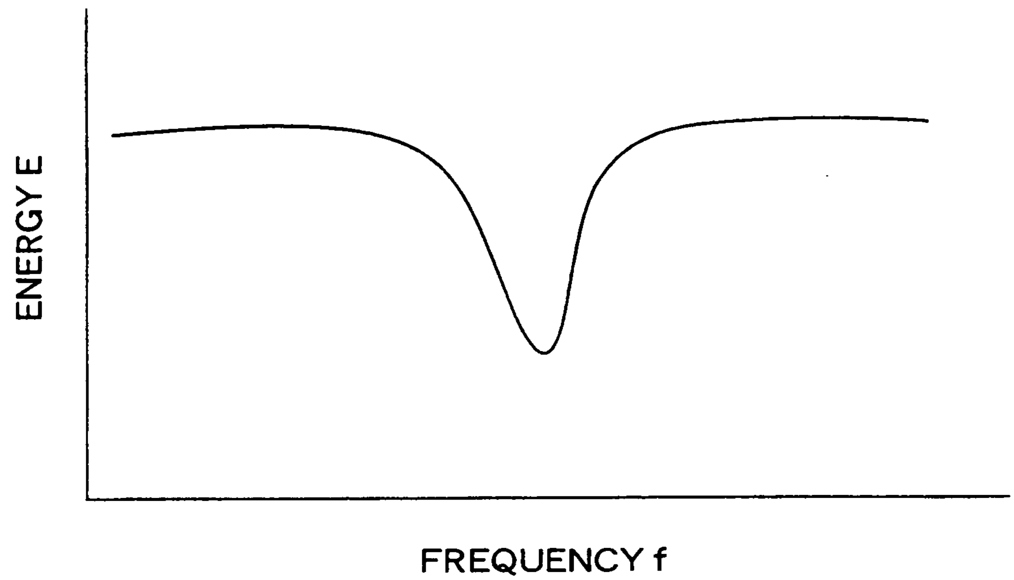


FIG. 5

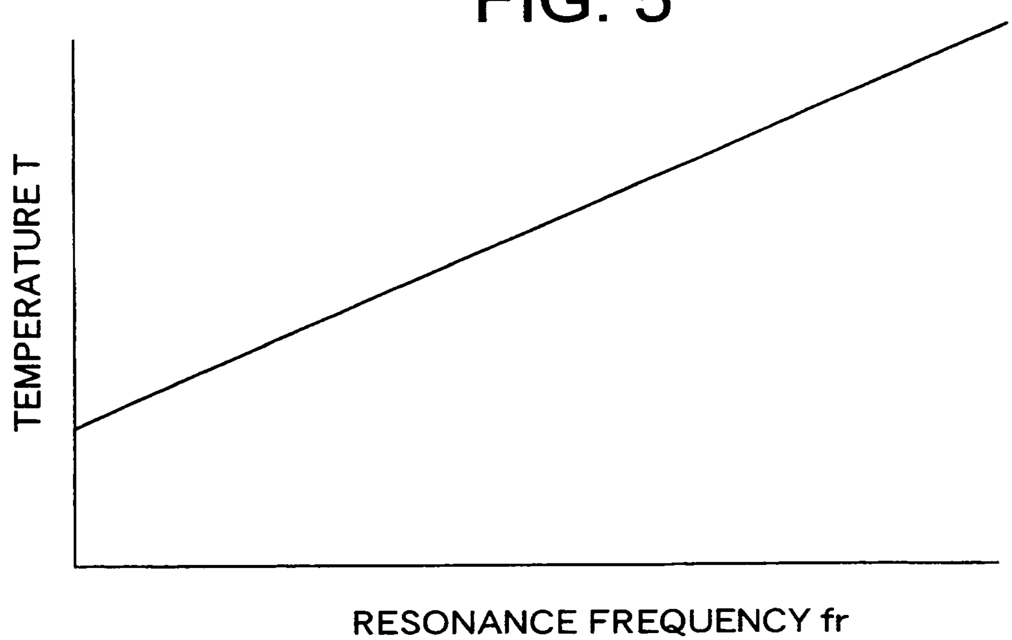
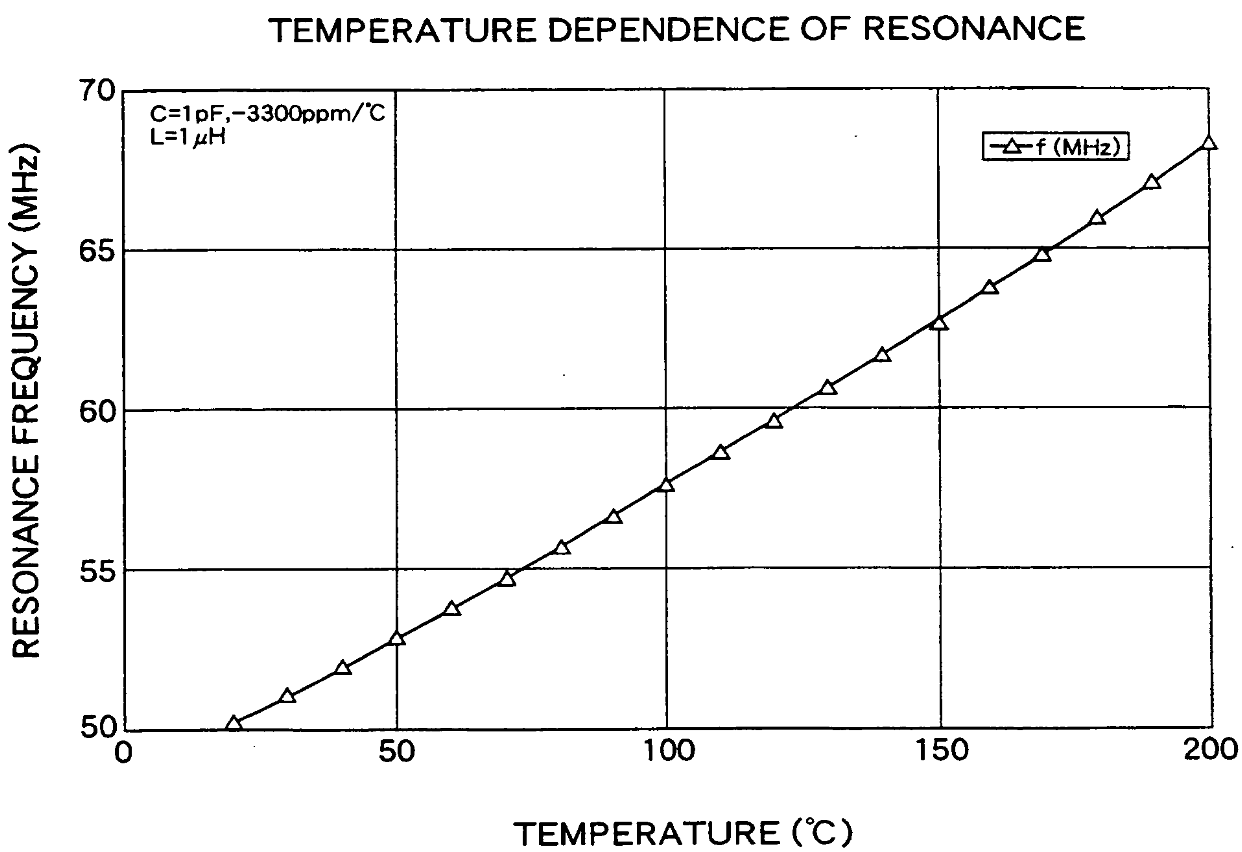


FIG. 6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L=1μH
f (MHz)
RESONANCE FREQUENCY (MHz)
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150
200
TEMPERATURE (℃)

FIG. 7A

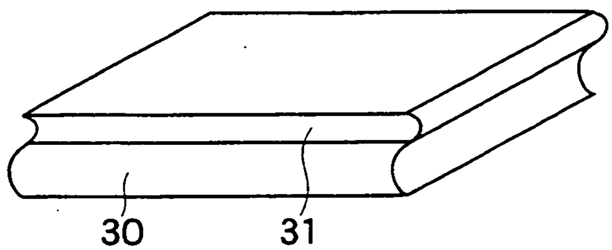

FIG. 7B

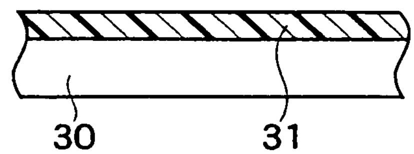

FIG. 7C

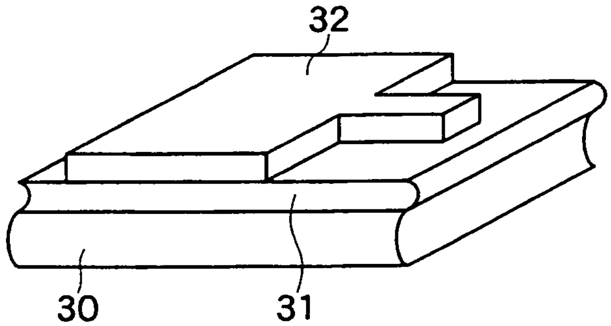

FIG. 7D

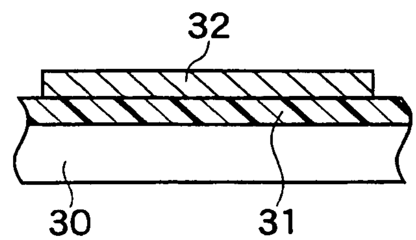

FIG. 7E

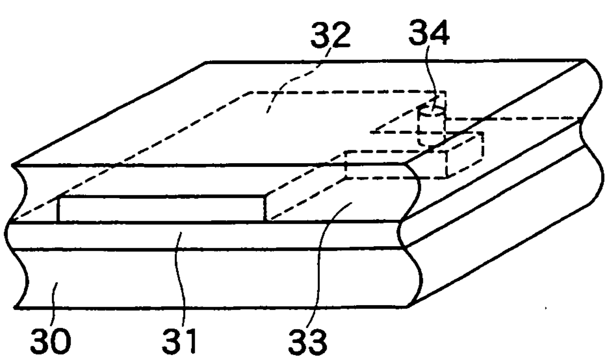

FIG. 7F

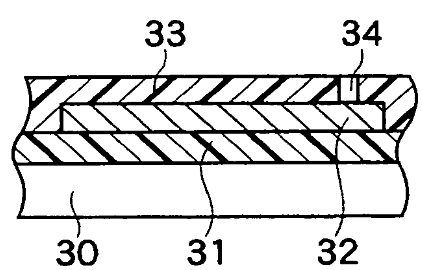

FIG. 8B

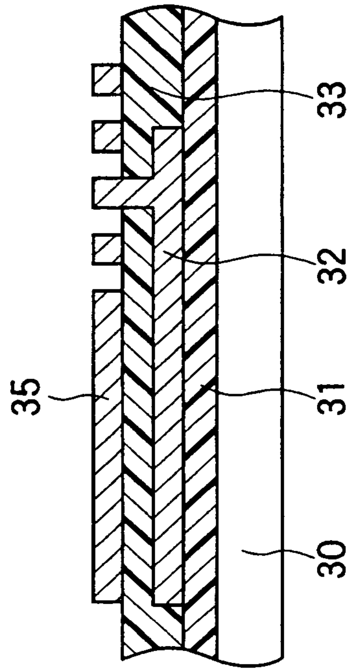

FIG. 8A

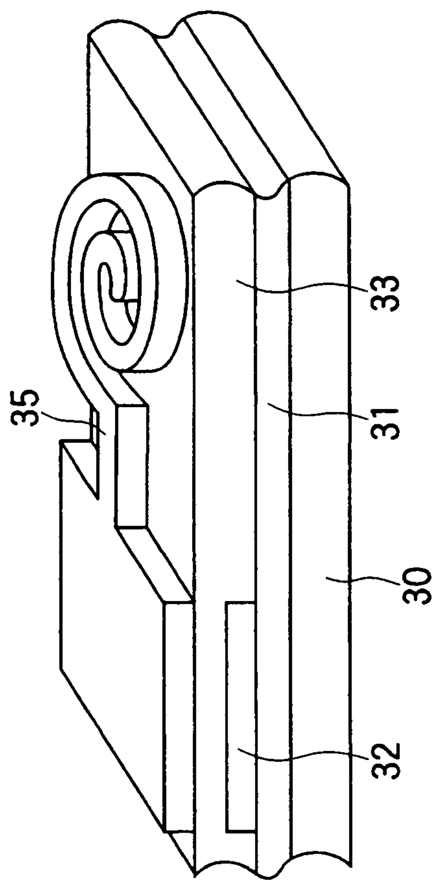

FIG. 9

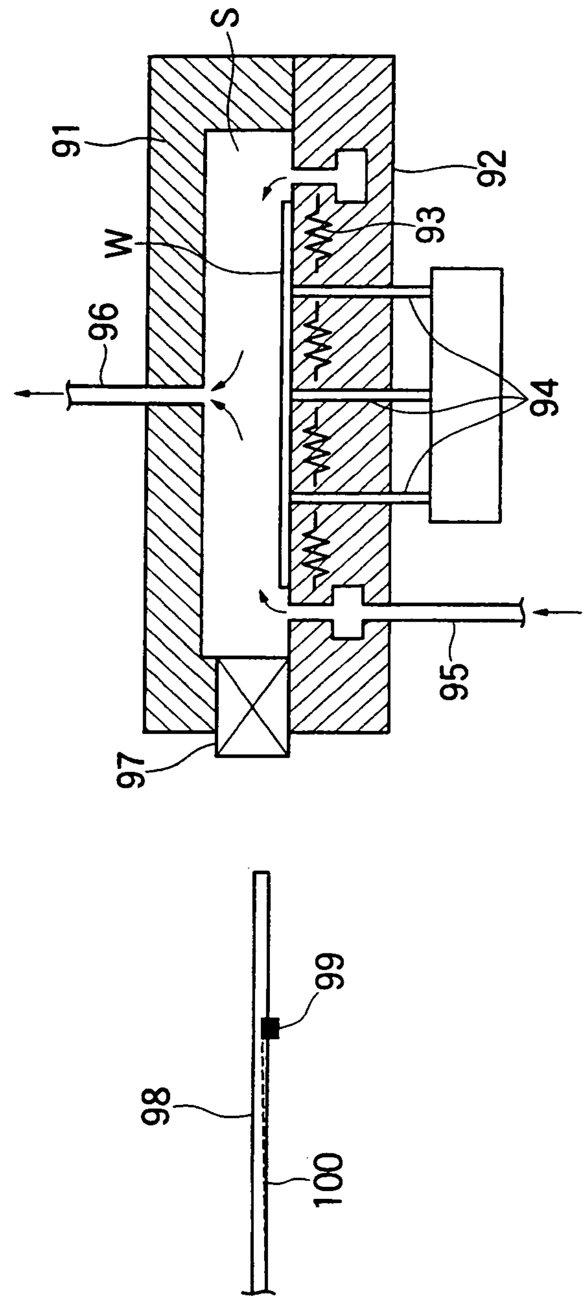

FIG. 10

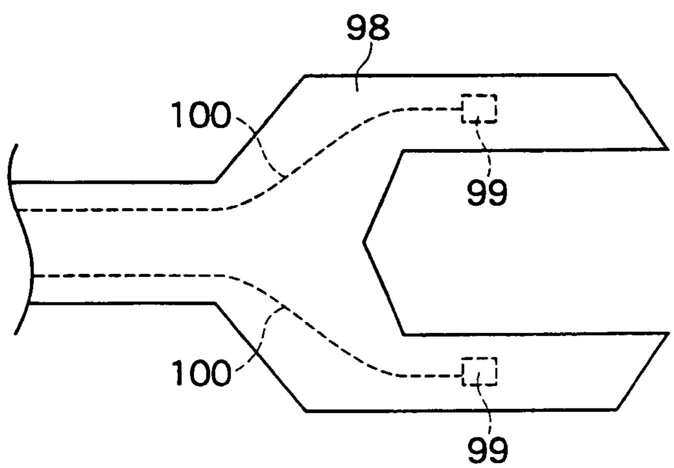

FIG. 11

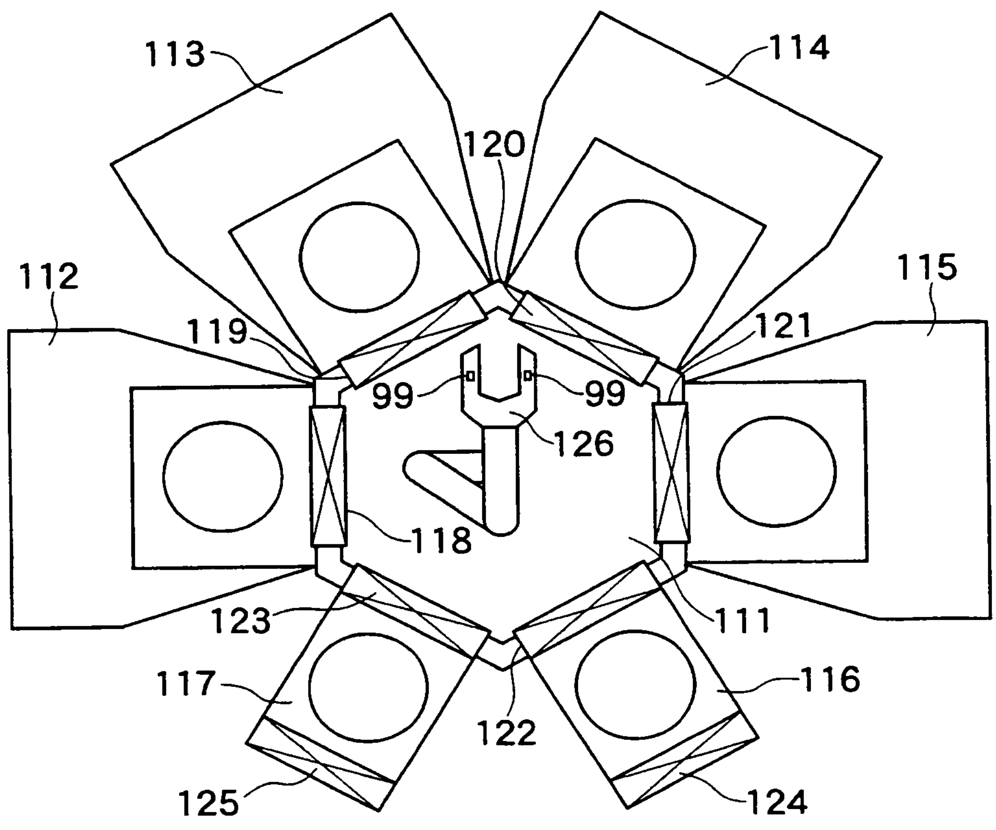

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FIG. 12

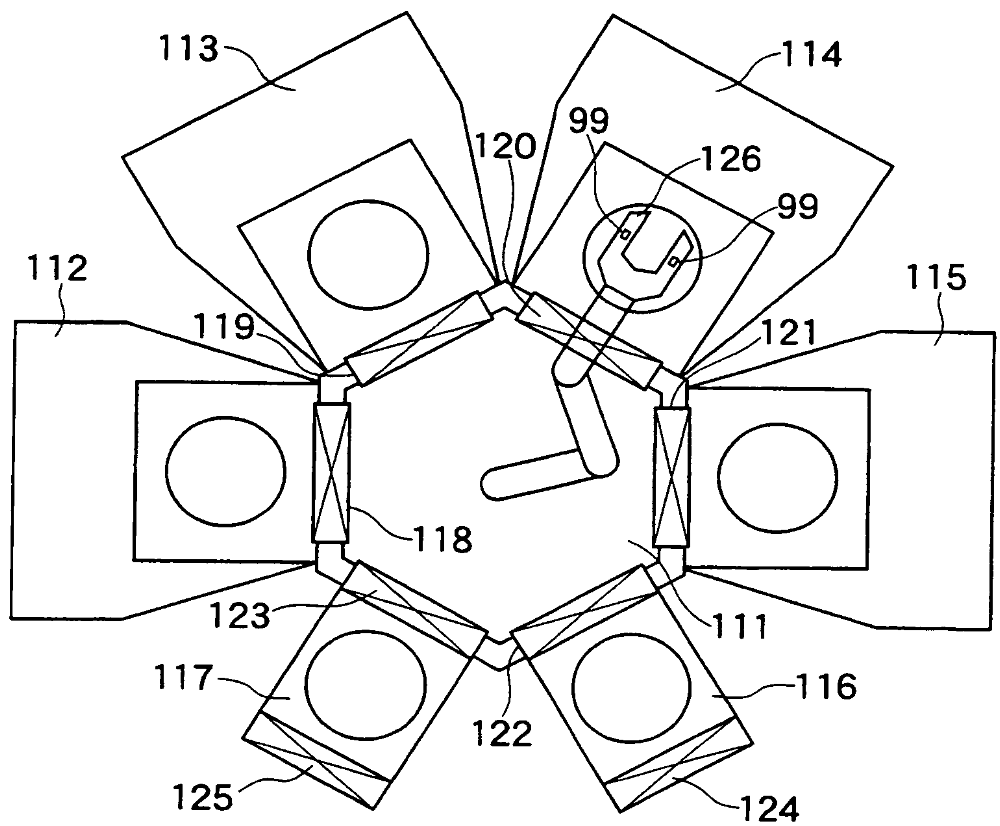
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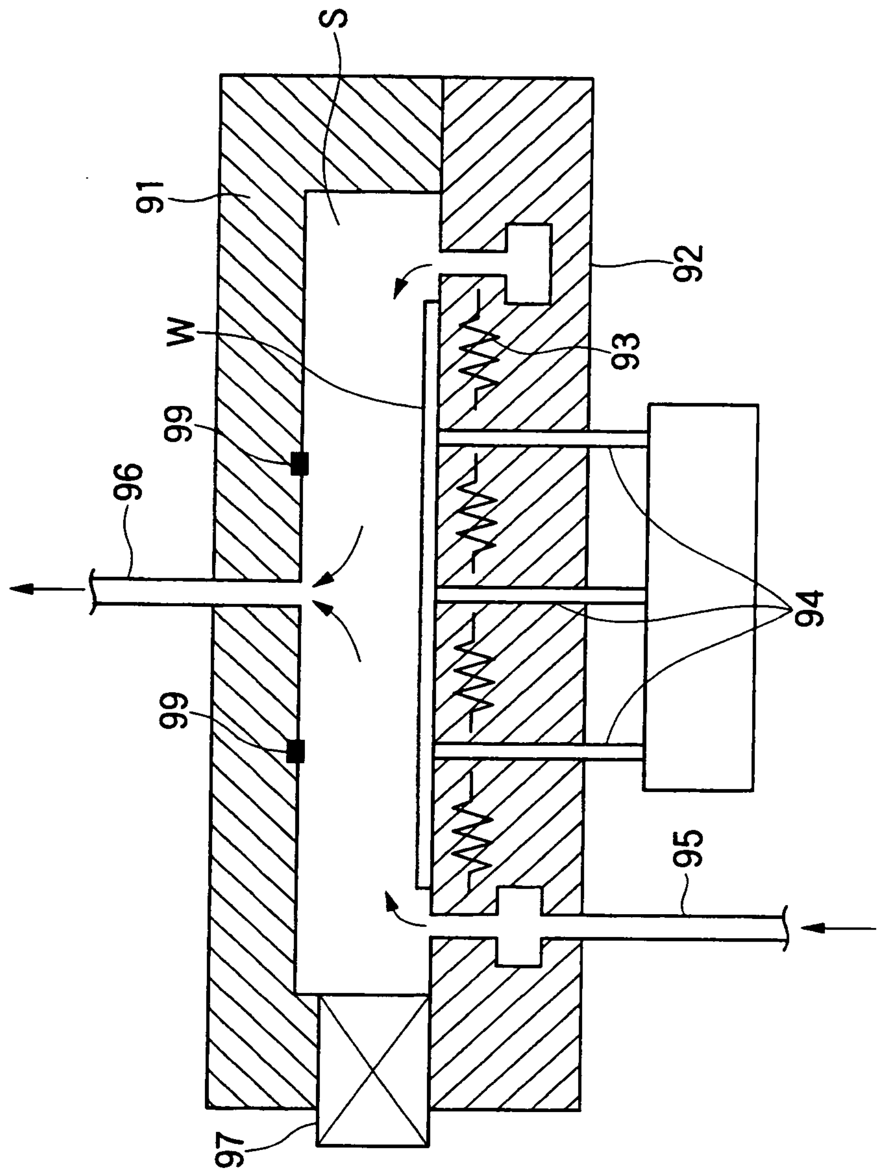
FIG. 13



INTERNATIONAL SEARCH REPORT

International Application No
PCT/JP 01/00564

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G01K7/32

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G01K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	PATENT ABSTRACTS OF JAPAN vol. 1995, no. 03, 28 April 1995 (1995-04-28) & JP 06 331454 A (HITACHI), 2 December 1994 (1994-12-02) abstract ---	1,7,9,12
A	EP 0 644 409 A (AT & T GLOBAL INF SOLUTION) 22 March 1995 (1995-03-22) abstract ---	1,12
A	US 5 576 224 A (YAKURA JAMES P ET AL) 19 November 1996 (1996-11-19) abstract --- -/--	9

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
7 May 2001	16/05/2001

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	De Buyzer, H

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INTERNATIONAL SEARCH REPORT

International Application No
PCT/JP 01/00564

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
A	WO 98 20316 A (REICHLE ROGER ;MAIO MARCO DI (GB); EURATOM (LU)) 14 May 1998 (1998-05-14) abstract	1
A	US 5 820 266 A (FEDAK TIBOR J) 13 October 1998 (1998-10-13) column 7, line 45 -column 8, line 42	7,13

2

INTERNATIONAL SEARCH REPORT

Information on patent family members

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PCT/JP 01/00564

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US 5576224 A	19-11-1996	US 5466614 A	14-11-1995
		EP 0644409 A	22-03-1995
		JP 7106392 A	21-04-1995
WO 9820316 A	14-05-1998	EP 0937236 A	25-08-1999
US 5820266 A	13-10-1998	NONE	